PARAMETRIC SURFACES FOR TOPOLOGY AND SHAPE OPTIMIZATIONS

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Topology optimization has drawn significant attention in recent development of structural optimization. This method has been proven very effective in determining the initial geometric layout for structural designs. The main drawback of the method, however, is that the topology optimization always leads to a non-smooth structural geometry, while most of the engineering applications require a smooth geometric shape, especially for manufacturing. On the other hand, shape optimization starts with a smooth geometric model that can be manufactured. However, a final optimal shape will be confined to the topology of its initial geometry. No holes can be created nor removed during the shape optimization process. The topology and shape optimizations must be combined to support structural design more effectively. The essential step that supports the integration is constructing smooth surfaces that not only approximate the structural layout obtained from topology optimization but also support design parameterization for shape optimization.

In general, the surfaces constructed from the structural layout for shape optimization must be accurate, parametric, smooth, compatible to existing CAD systems for manufacturing, and having a reasonable number of degrees of freedom for design changes. The surfaces must accurately capture the structural layout, ideally, within a prescribed error margin. Note that the error margin can be relaxed if a shape optimization follows. The best freeform surface that is parametric, smooth and compatible to CAD systems is B-spline surface. Smoothness of a B-spline surface is determined by the polynomial orders of its basis functions. In addition, shape of the surface is determined by its control point positions, which are naturally selected as design variables for shape optimization. Usually, a minimum number of control points can be obtained for a prescribed error margin and the required surface smoothness. The smoothness of the B-spline surfaces is determined by the polynomial order of their basis functions. The parametric surfaces can be imported into CAD systems analytically through the Application Protocol Interfaces (API) of the CAD systems.

The objectives of this paper are investigating advanced geometric modeling approaches for constructing smooth parametric B-spline surfaces that serve the purpose of integrating topology and shape optimizations. The focus is on 3-D solid applications.

There are very rich publications addressing surface construction from discrete points in the areas of computer-aided geometric modeling and reverse engineering. These methods can be categorized into three main approaches: (i) least square curve fitting and surface skinning, (ii) surface construction from ordered or disarrayed points using least square method, and (iii) surface construction from surface mesh of general topology. The first two approaches support constructing smooth surfaces with simple topology since a single B-spline patch, which contains a number of smaller surfaces, is constructed. The third approach constructs G^1-continuous surfaces with arbitrary topology, yielding a network of B-spline patches. Pros and cons of individual methods and their limitations will be discussed. Examples will be presented to illustrate adequacy as well as pros and cons of methods discussed.

This paper clearly contributes to the integration of topology and shape optimizations by examining the most advanced surface construction methods and identifying their adequacy for shape optimization. However, work is needed for automating the surface fitting method for randomly distributed points. In addition, converting B-spline surface models to CAD solid features for CAD-based optimization requires further research.